

**Table 12.1 – Renewable Energy Impacts Calculation**

Conversion Formula:

Step 1      Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)

Step 2      Annual Electricity Generation (D) x Competing Heat Rate (E) = Annual Output (F)

Step 3      Annual Output (F) x Emissions Coefficient (G) = Annual Emissions Displaced (H)

<b>Technology</b>	<b>Wind</b>	<b>Geothermal</b>	<b>Biomass</b>	<b>Hydropower</b>	<b>PV</b>	<b>Solar Thermal</b>
(A) Capacity (kW)	8,181,033	2,189,957	6,417,795	79,103,834	168,977	440,800
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	44.2%	22.5%	24.4%
(C) Annual Hours	8,760	8,760	8,760	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	25,799,706,093	17,265,620,227	44,975,908,630	306,239,675,812	333,053,696	705,355,200
(E) Competing Heat Rate (Btu/kWh)	10,107	10,107	10,107	10,107	10,107	10,107
(F) Annual Output (Trillion Btu)	261	175	455	3,095	3	7
(G) Carbon Coefficient (MMTCB/Trillion Btu)	0.01783	0.01783	0.01783	0.01783	0.01783	0.01783
(H) Annual Carbon Displaced (MMTC)	4.649	3.111	8.105	55.187	0.060	0.128

**Sources:** Capacity: EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16, 2005.

Capacity factors: Hydropower calculated from EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16. All others based on DOE, *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997, and program data.

Heat Rate: EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table A6.

Carbon Coefficient: DOE, GPRA2003 Data Call, Appendix B, page B-16, 2003.

**Notes:**

Capacity values exclude combined-heat-and-power (CHP) data but include end-use sector (industrial and commercial) non-CHP data.

Competing heat rate from Fossil-Fueled Steam-Electric Plants heat rate.

**Table 12.2 – Number of Home Electricity Needs Met Calculation**

*Conversion Formula:*      *Step 1*      *Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)*  
    *Step 2*      *Annual Electricity Generation (D) / Average Consumption (E) = Number of Households (F)*

<b>Technology</b>	<b><u>Wind</u></b>	<b><u>Geothermal</u></b>	<b><u>Biomass</u></b>	<b><u>Hydropower</u></b>	<b><u>PV</u></b>	<b><u>Solar Thermal</u></b>
(A) Capacity (kW)	8,181,033	2,189,957	6,417,795	79,103,834	168,977	440,800
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	44.2%	22.5%	24.4%
(C) Annual Hours	8,760	8,760	8,760	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	25,799,706,093	17,265,620,227	44,975,908,630	306,239,675,812	333,053,696	942,183,512
(E) Average Annual Household Electricity Consumption (kWh)	11,586	11,586	11,586	11,586	11,586	11,586
(F) Number of Households	2,226,809	1,490,220	3,881,935	26,431,984	28,746	81,321

**Sources:** Capacity: EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16, 2005.

Capacity factors: Hydropower calculated from EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16. All others based on DOE, *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997, and program data.

Household electricity consumption: EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February), Tables A4 and A8, 2005.

**Notes:**

Capacity values exclude combined-heat-and-power (CHP) data but include end-use sector (industrial and commercial) non-CHP data.

**Table 12.3 – Coal Displacement Calculation**

<i>Conversion Formula:</i>	<i>Step 1</i>	<i>Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)</i>
	<i>Step 2</i>	<i>Annual Electricity Generation (D) x Conversion Efficiency (E) = Total Output (F)</i>
	<i>Step 3</i>	<i>Total Output (F) / Fuel Heat Rate (G) = Quantity Fuel (H)</i>

<b>Technology</b>	<b><u>Wind</u></b>	<b><u>Geothermal</u></b>	<b><u>Biomass</u></b>	<b><u>Hydropower</u></b>	<b><u>PV</u></b>	<b><u>Solar Thermal</u></b>
(A) Capacity (kW)	8,181,033	2,189,957	6,417,795	79,103,834	168,977	440,800
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	44.2%	22.5%	24.4%
(C) Annual Hours	8,760	8,760	8,760	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	25,799,706,093	17,265,620,227	44,975,908,630	306,239,675,812	333,053,696	942,183,512
(E) Competing Heat Rate (Btu/kWh)	10,107	10,107	10,107	10,107	10,107	10,107
(F) Total Output (Btu)	260,757,629,480,278	174,503,623,632,874	454,571,508,527,161	3,095,164,403,427,280	3,366,173,705,613	9,522,648,757,289
(G) Coal Heat Rate (Btu per short ton)	20,381,000	20,381,000	20,381,000	20,381,000	20,381,000	20,381,000
(H) Coal (short tons)	12,794,153	8,562,074	22,303,690	151,865,188	165,162	467,232

**Sources:** Capacity: EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16, 2005.

Capacity factors: Hydropower calculated from EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16. All others based on DOE, *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997 and Program data.

Conversion Efficiency: EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table A6.

Heat Rate: *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table H1.

**Notes:**

Capacity values exclude combined-heat-and-power (CHP) data but include end-use sector (industrial and commercial) non-CHP data.

**Table 12.4 – National SO<sub>2</sub> and Heat Input Data**

	<u><b>1980</b></u>	<u><b>1985</b></u>	<u><b>1990</b></u>	<u><b>1995</b></u>	<u><b>2000</b></u>	<u><b>2003</b></u>
SO <sub>2</sub> (lbs)	34,523,334,000	32,184,330,000	31,466,566,000	23,667,789,600	22,404,913,800	21,189,064,800
Heat (MMBtu)	17,838,745,941	18,414,433,865	19,684,094,492	21,874,579,916	25,603,420,992	26,000,023,795
SO <sub>2</sub> Heat Factor (lb/MMBtu)	1.935	1.748	1.599	1.082	0.875	0.815

**Source:** EPA, Clean Air Markets Web site - Data and Maps, Emissions section, <http://cfpub.epa.gov/gdm/>

**Table 12.5 – SO<sub>2</sub>, NO<sub>x</sub>, CO<sub>2</sub> Emission Factors for Coal Fired and Non-Coal Fired Title IV Affected Units**

	<u>1996</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>
SO <sub>2</sub> (lbs/mmBtu)							
Coal	1.241	1.245	1.222	1.166	1.036	1.008	0.976
Non-Coal	0.246	0.256	0.318	0.267	0.200	0.220	0.126
Total	1.096	1.093	1.058	0.999	0.875	0.843	0.794
NO <sub>x</sub> (lbs/mmBtu)							
Coal	0.568	0.559	0.532	0.487	0.444	0.425	0.408
Non-Coal	0.221	0.234	0.251	0.244	0.210	0.176	0.128
Total	0.518	0.509	0.481	0.442	0.399	0.373	0.348
CO <sub>2</sub> (lbs/mmBtu)							
Coal	206.377	205.537	205.677	205.586	205.646	205.627	205.672
Non-Coal	132.731	130.804	131.685	132.001	133.110	130.159	126.858
Total	195.682	194.056	192.256	191.956	191.672	189.809	188.813

**Source:** EPA, Acid Rain Program Compliance Report 2001, Emission Scorecard, updated April 2003, Table 1, <http://www.epa.gov/airmarkets/emissions/score01/index.html>, and EPA, Clean Air Markets Web site - Data and Maps, Emissions section, <http://cfpub.epa.gov/gdm/>

**Table 12.6a – Sulfur Dioxide, Nitrogen Oxide, and Carbon Dioxide Emission Factors, 2003 - Electricity Generators**

Fuel	Boiler Type/ Firing Configuration	Emission Factors		
		Sulfur Dioxide <sup>1</sup>	Nitrogen Oxides <sup>2</sup>	Carbon Dioxide <sup>3</sup>
<b>Electricity Generators</b>				lbs per 10 <sup>6</sup> Btu
Coal and Other Solid Fuels		lbs per ton	lbs per ton	
Petroleum Coke <sup>4</sup>	fluidized bed <sup>5</sup>	39.0 x S	21	225.13
	all others	39.0 x S	21	225.13
Refuse	all types	3.9	5	199.82
Wood	all types	0.08	1.5	0
		lbs per 10 <sup>3</sup> gal	lbs per 10 <sup>3</sup> gal	lbs per 10 <sup>6</sup> Btu
Petroleum and Other Liquid Fuels				
Residual Oil <sup>6</sup>	tangential	157.0 x S	32	173.72
	vertical	157.0 x S	47	173.72
	all others	157.0 x S	47	173.72
Distillate Oil <sup>6</sup>	all types	150.0 x S	24	161.27
Methanol	all types	0.05	12.4	138.15
Propane (liquid)	all types	86.5	19	139.04
Coal-Oil Mixture	all types	185.00 x S	50	173.72
		lbs per 10 <sup>6</sup> cf	lbs per 10 <sup>6</sup> cf	lbs per 10 <sup>6</sup> Btu
Natural Gas and Other Gaseous Fuels				
Natural Gas	tangential	0.6	170	116.97
	all others	0.6	280	116.97
Blast Furnace Gas	all types	950	280	116.97

**Source:** EIA, Electric Power Annual 2003, DOE/EIA-0348(2003) (Washington, D.C., December 2004) Table A1

**Notes:**

<sup>1</sup> Uncontrolled sulfur dioxide emission factors. "x S" indicates that the constant must be multiplied by the percentage (by weight) of sulfur in the fuel. Sulfur dioxide emission estimates from facilities with flue gas desulfurization equipment are calculated by multiplying uncontrolled emission estimates by one minus the reported sulfur removal efficiencies. Sulfur dioxide emission factors also account for small quantities of sulfur trioxide and gaseous sulfates.

<sup>2</sup> Parenthetic values are for wet bottom boilers; otherwise dry bottom boilers. If bottom type is unknown, dry bottom is assumed. Emission factors are for boilers with a gross heat rate of 100 million Btu per hour or greater.

<sup>3</sup> Uncontrolled carbon dioxide emission estimates are reduced by 1% to account for unburned carbon.

<sup>4</sup> Emission factors for petroleum coke are assumed to be the same as those for anthracite. If the sulfur content of petroleum coke is unknown, a 6 percent sulfur content is assumed.

<sup>5</sup> Sulfur dioxide emission estimates from fluidized bed boilers assume a sulfur removal efficiency of 90%.

<sup>6</sup> Oil types are categorized by Btu content as follows: heavy (greater than or equal to 144,190 Btu per gallon), and light (less than 144,190 Btu per gallon). cf = Cubic Feet. gal = U.S. Gallons. lbs = Pounds.

**Table 12.6b – Sulfur Dioxide, Nitrogen Oxide, and Carbon Dioxide Emission Factors, 2003 - Combined Heat and Power Producers**

Fuel	Boiler Type/ Firing Configuration	Emission Factors		
		Sulfur Dioxide <sup>1</sup>	Nitrogen Oxides <sup>2</sup>	Carbon Dioxide <sup>3</sup>
		lbs per ton	lbs per ton	lbs per 10 <sup>6</sup> Btu
Coal and Other Solid Fuels				
Peat.	all types	30.00 x S	12	0
Agricultural Waste	all types	0.08	1.2	0
Black Liquor	all types	7	1.5	0
Chemicals	all types	7	1.5	0
Closed Loop Biomass	all types	0.08	1.5	0
Internal	all types	0.08	1.5	0
Liquid Acetonitrile Waste	all types	7	1.5	150.76
Liquid Waste	all types	2.8	2.3	163.29
Municipal Solid Waste	all types	1.7	5.9	189.48
Petroleum Coke	all types	39.00 x S	14	225.13
Pitch	all types	30.00 x S	11.1	0
RailRoad Ties	all types	0.08	1.5	0
Red Liquor.	all types	7	1.5	0
Sludge	all types	2.8	5	0
Sludge Waste	all types	2.8	5	0
Sludge Wood	all types	2.8	5	0
Spent Sulfite Liquor	all types	7	1.5	0
Straw	all types	0.08	1.5	0
Sulfur	all types	7	0	0
Tar Coal	all types	30.00 x S	11.1	0
Tires	all types	38.00 x S	21.7	0
Waste Byproducts	all types	1.7	2.3	163.29
Waste Coal	all types	38.00 x S	21.7	0
Wood/Wood Waste	all types	0.08	1.5	0
Petroleum and Other Liquid Fuels		lbs per 10 <sup>3</sup> gal	lbs per 10 <sup>3</sup> gal	lbs per 10 <sup>6</sup> Btu
Heavy Oil <sup>4</sup>	all types	157.00 x S	47	173.72
Light Oil <sup>4</sup>	all types	142.00 x S	20	159.41
Diesel	all types	142.00 x S	20	161.27
Kerosene	all types	142.00 x S	20	159.41
Butane (liquid)	all types	0.09	21	143.2
Fish Oil	all types	0.5	12.4	0
Methanol	all types	0.5	12.4	138.15
Oil Waste	all types	147.00 x S	19	163.61
Propane (liquid)	all types	0.5	19	139.04
Sludge Oil	all types	147.00 x S	19	0
Tar Oil	all types	162.70 x S	67	0
Waste Alcohol	all types	0.5	12.4	138.15

Natural Gas and Other Gaseous Fuels		lbs per 10 <sup>6</sup> cf	lbs per 10 <sup>6</sup> cf	lbs per 10 <sup>6</sup> Btu
Natural Gas	all types	0.6	280	116.97
Butane (Gas)	all types	0.6	21	143.2
Hydrogen	all types	0	550	0
Landfill Gas	all types	0.6	550	115.12
Methane	all types	0.6	550	115.11
Other Gas	all types	0.6	550	141.54
Propane (Gas)	all types	0.6	19	139.04

**Source:** EIA, Electric Power Annual 2003, DOE/EIA-0348(2003) (Washington, D.C., December 2004)  
Table A1

**Notes:**

<sup>1</sup> Uncontrolled sulfur dioxide emission factors. "x S" indicates that the constant must be multiplied by the percentage (by weight) of sulfur in the fuel. Sulfur dioxide emission estimates from facilities with flue gas desulfurization equipment are calculated by multiplying uncontrolled emission estimates by one minus the reported sulfur removal efficiencies. Sulfur dioxide emission factors also account for small quantities of sulfur trioxide and gaseous sulfates.

<sup>2</sup> Parenthetic values are for wet bottom boilers; otherwise dry bottom boilers. If bottom type is unknown, dry bottom is assumed. Emission factors are for boilers with a gross heat rate of 100 million Btu per hour or greater.

<sup>3</sup> Uncontrolled carbon dioxide emission estimates are reduced by 1% to account for unburned carbon.

<sup>4</sup> Oil types are categorized by Btu content as follows: heavy (greater than or equal to 144,190 Btu per gallon), and light (less than 144,190 Btu per gallon). cf = Cubic Feet. gal = U.S. Gallons. lbs = Pounds.



**Table 12.7 – Global Warming Potentials (GWP)**

(100-year time horizon)

Gas	GWP
	SAR
Carbon dioxide (CO <sub>2</sub> )	1
Methane (CH <sub>4</sub> ) <sup>1</sup>	21
Nitrous oxide (N <sub>2</sub> O)	310
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF <sub>4</sub>	6,500
C <sub>2</sub> F <sub>6</sub>	9,200
C <sub>4</sub> F <sub>10</sub>	7,000
C <sub>6</sub> F <sub>14</sub>	7,400
SF <sub>6</sub>	23,900

**Source:** EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003*, EPA 430-R-05-004 (PUBLIC DRAFT FEBRUARY 2005), Table ES-1.

**Notes:**

The GWP of a greenhouse gas is the ratio of global warming, or radiative forcing – both direct and indirect – from one unit mass of a greenhouse gas to that of one unit mass of carbon dioxide over a period of time.

GWP from Intergovernmental Panel and Climate Change (IPCC) Second Assessment Report (SAR) and Third Assessment Report (TAR).

Although the GWPs have been updated by the IPCC, estimates of emissions presented in this report use the GWPs from the Second Assessment Report. The UNFCCC reporting guidelines for national inventories were updated in 2002, but continue to require the use of GWPs from the SAR so that current estimates of aggregated greenhouse gas emissions for 1990 through 2001 are consistent with estimates developed prior to the publication of the TAR. Therefore, to comply with international reporting standards under the UNFCCC, official emission estimates are reported by the United States using SAR GWP values.

<sup>1</sup> The methane GWP includes direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor.

The indirect effect due to the production of CO<sub>2</sub> is not included.

**Table 12.8 – Approximate Heat Content of Selected Fuels for Electric Power Generation**

**Fossil Fuels <sup>1</sup>**

Residual Oil (million Btu per barrel)	6.287
Distillate Oil (million Btu per barrel)	5.825
Natural Gas (Btu per million cubic ft)	1,020
Coal (million Btu per Short Ton)	20.381

**Biomass Materials <sup>2</sup>**

Switchgrass Btu per pound	7,341
Bagasse, Btu per pound	6,065
Rice Hulls, Btu per pound	6,575
Poultry Litter, Btu per pound	6,187
Solid wood waste, Btu per pound	6-8,000

**Sources:**

1. EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table H1.

2. Animal Waste Screening Study, Electrotek Concepts, Inc., Arlington, VA. June 2001.

**Table 12.9 – Approximate Heat Rates for Electricity**

(Btu per Kilowatthour)

	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>	<u>2003</u>
Fossil-Fueled Steam-Electric Plants <sup>1</sup>	10,388	10,402	10,201	10,146	10,119	10,107
Nuclear Steam-Electric Plants <sup>2</sup>	10,908	10,582	10,429	10,448	10,439	10,439
Geothermal Energy Plants <sup>3</sup>	21,639	21,096	21,017	21,017	21,017	21,017

**Source:** EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., September 2004), Table A6

**Notes:**

<sup>1</sup> Through 2000, used as the thermal conversion factor for wood and waste electricity net generation at electric utilities. For all years, used as the thermal conversion factor for hydroelectric, solar, and wind electricity net generation. Through 2000, heat rates are for fossil-fueled steam-electric plants at electric utilities. For 2001 and 2002, heat rates are for fossil-fueled steam-electric plants at electric utilities and independent power producers. For 2003, the heat rate is for all fossil-fueled plants at electric utilities and independent power producers

<sup>2</sup> Used as the thermal conversion factor for nuclear electricity net generation.

<sup>3</sup> Used as the thermal conversion factor for geothermal electricity net generation

**Table 12.10 – Heating Degree Days by Month**

	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>	<u>2003</u>	<u>2004</u>	<u>Normal</u> <sup>1</sup>
January	887	728	886	935	778	940	957	917
February	831	655	643	725	670	819	769	732
March	680	535	494	669	624	564	487	593
April	338	321	341	302	282	351	302	345
May	142	184	115	115	185	162	NA	159
June	49	29	29	29	23	39	NA	39
July	5	6	12	8	3	2	NA	9
August	10	10	12	6	8	2	NA	15
September	54	56	69	71	38	59	NA	77
October	316	246	244	267	299	252	NA	282
November	564	457	610	400	561	477	NA	539
December	831	789	1,005	696	813	773	NA	817
Total	4,707	4,016	4,460	4,223	4,284	4,440	NA	4,524

**Source:** EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., September 2004), Table 1.7

**Notes:**

<sup>1</sup> Based on calculations of data from 1971-2000

Data exclude Alaska and Hawaii. Beginning in 2002, data are weighted by the estimated 2000 population. The population-weighted state figures are aggregated into Census divisions and the national average.

**Table 12.11 – Cooling Degree Days by Month**

	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>	<u>2003</u>	<u>2004</u>	<u>Normal</u> <sup>1</sup>
January	9	15	10	3	8	2	5	9
February	4	14	10	12	6	6	5	8
March	13	21	25	11	17	20	26	18
April	23	29	28	37	53	38	41	30
May	95	86	131	114	92	106	NA	97
June	199	234	221	220	242	196	NA	213
July	374	316	284	302	369	334	NA	321
August	347	291	302	333	331	332	NA	290
September	192	172	156	138	202	155	NA	155
October	42	57	50	46	57	64	NA	53
November	10	16	8	18	11	24	NA	15
December	5	9	4	11	5	4	NA	8
Total	1,313	1,260	1,229	1,245	1,393	1,281	NA	1,215

**Source:** EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., September 2004), Table 1.8

**Notes:**

<sup>1</sup> Based on calculations of data from 1971-2000

Data exclude Alaska and Hawaii. Beginning in 2002, data are weighted by the estimated 2000 population. The population-weighted state figures are aggregated into Census divisions and the national average.

NA = Not Available